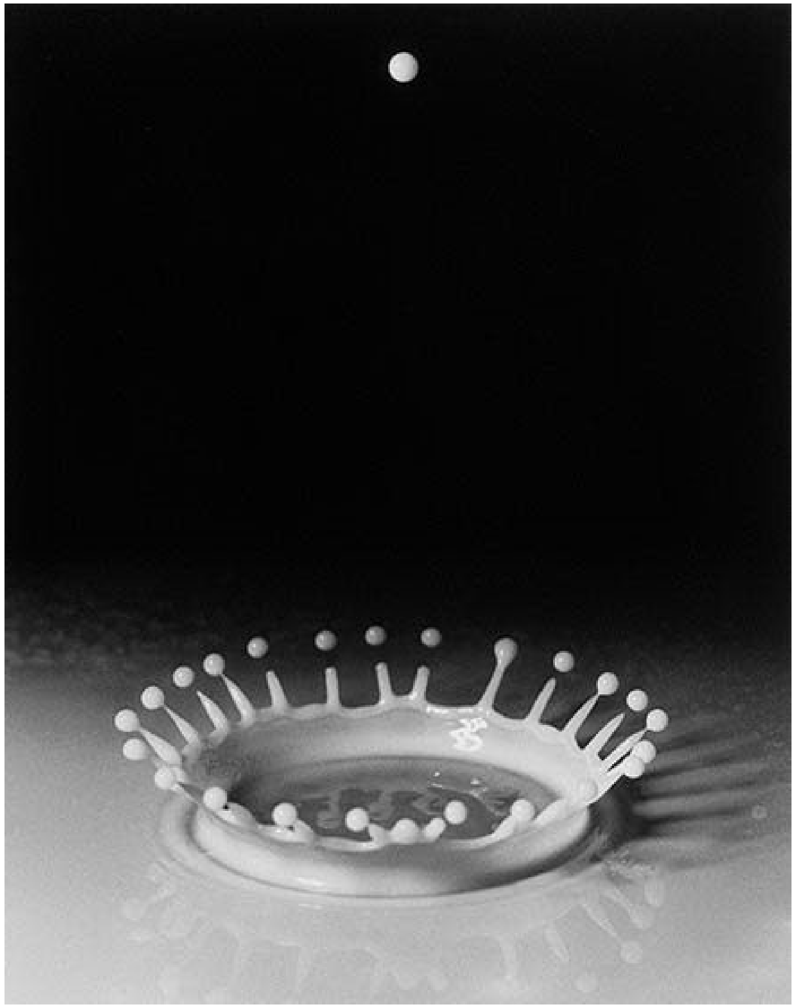
Explosion on Surface of Star

Making a Splash--Breaking a Neck

The Making of Complexity in Physical Systems

Leo P. Kadanoff

University of Chicago
Chicago, Illinois
and Perimeter Institute
Waterloo, Ontario
email: LeoP@UChicago.edu



Splash:
A drop has hit the surface of
a glass of milk
Edgerton Photo

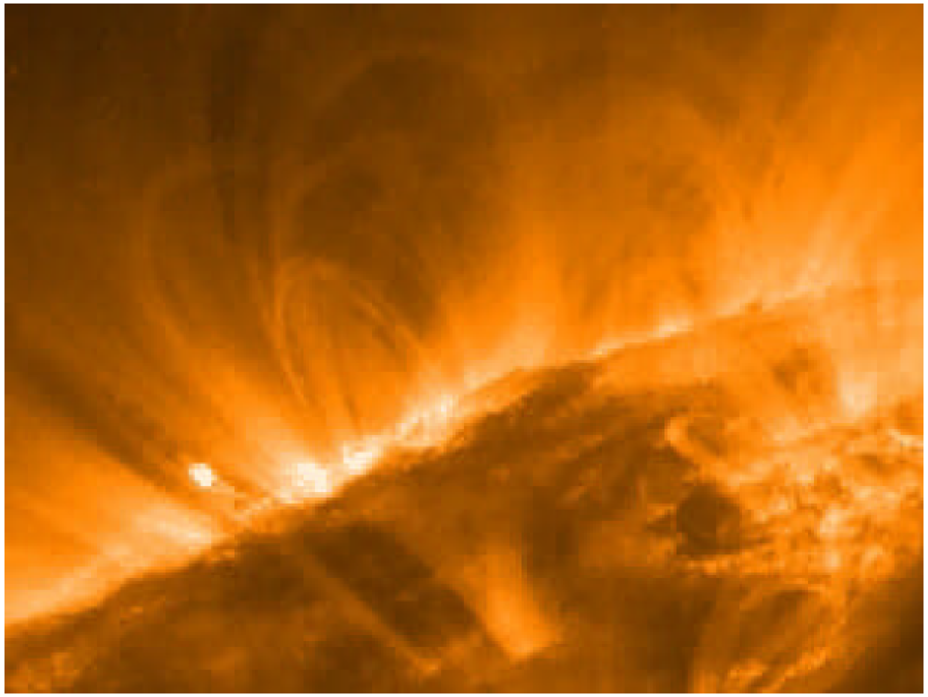
Summary of Talk

The fundamental laws of physics are very simple.

The world about us is very complex.

Living things are very complex indeed.

This complexity has led some thinkers to suggest that living things are not the outcome of physical law but instead the creation of a designer.



Credit: NASA/Trace

magnetic storm on surface of sun

Here I examine how complexity is produced naturally in fluids.

First Interlude: Intelligent Design

is the subject of a political and intellectual discussion Its proponents argue that biological systems are too complex to have been the product of a natural evolution, Darwinian or otherwise, but instead are the result of a fashioning by some (super-) intelligent creator (or Creator).

Proponents:
William Paley (1743-1805).
M. Behe, a biochemist who looks at cells
Bill Dembski, a philosopher and mathematician* who has theorems which describe a search process.

* I was his thesis adviser for his math Ph.D

“Political Context”: The Discovery Institute

The Discovery Institute supports Intelligent Design research and the spread of ID ideas as part of a “Wedge Strategy” which “seeks nothing less than the overthrow of materialism and its cultural legacies.” It has “re-opened the case for a broadly theistic understanding of nature.”

“We will move toward direct confrontation with the advocates of materialist science through challenge conferences in significant academic settings. We will also pursue ..... the integration of design theory into public school science curricula.“

Quotes are from their Wedge Document:
http://www.antievolution.org/features/wedge.html

What to do?

As academics we should consider the validity of the ID arguments with an open but critical mind.

As intelligent citizens, we should think about curricular issues for our schools. This talk is mostly about science, but it does return to school-issues at the end.

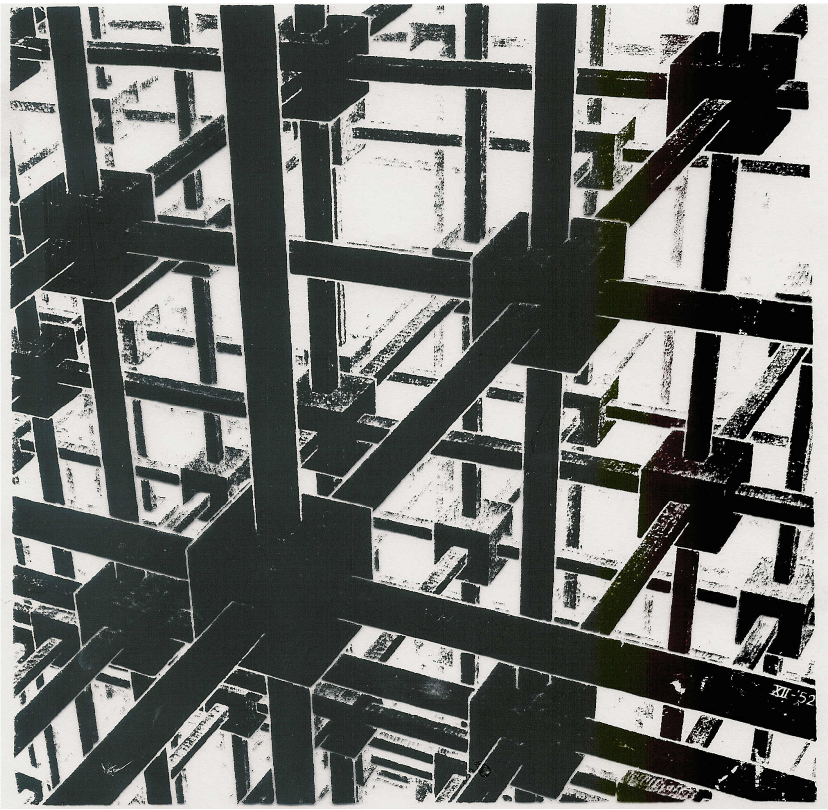
The Structure of Physics

The laws are simple, a few lines of partial differential equations to express rates of change of physical quantities in space and time.

The ideas are simple:

The world is lawful.
The same basic laws hold everywhere and always.
New domains of nature may inspire new laws, but all the different laws are consistent with one another.

Everything is simple, neat, and expressible in terms of everyday mathematics, usually partial differential equations.



Esher’s framework

Everything is simple and neat--except, of course, the world.

Before understanding comes observation…..

We ask: Why is the world so complicated?

Type I Complexity

Structures repeated with variations in size shape placement.

Type I Complexity

Structures repeated with variations in size shape placement.

flow past cylinder

Type I Complexity

Structures repeated with variations in size shape placement.

flow past cylinder

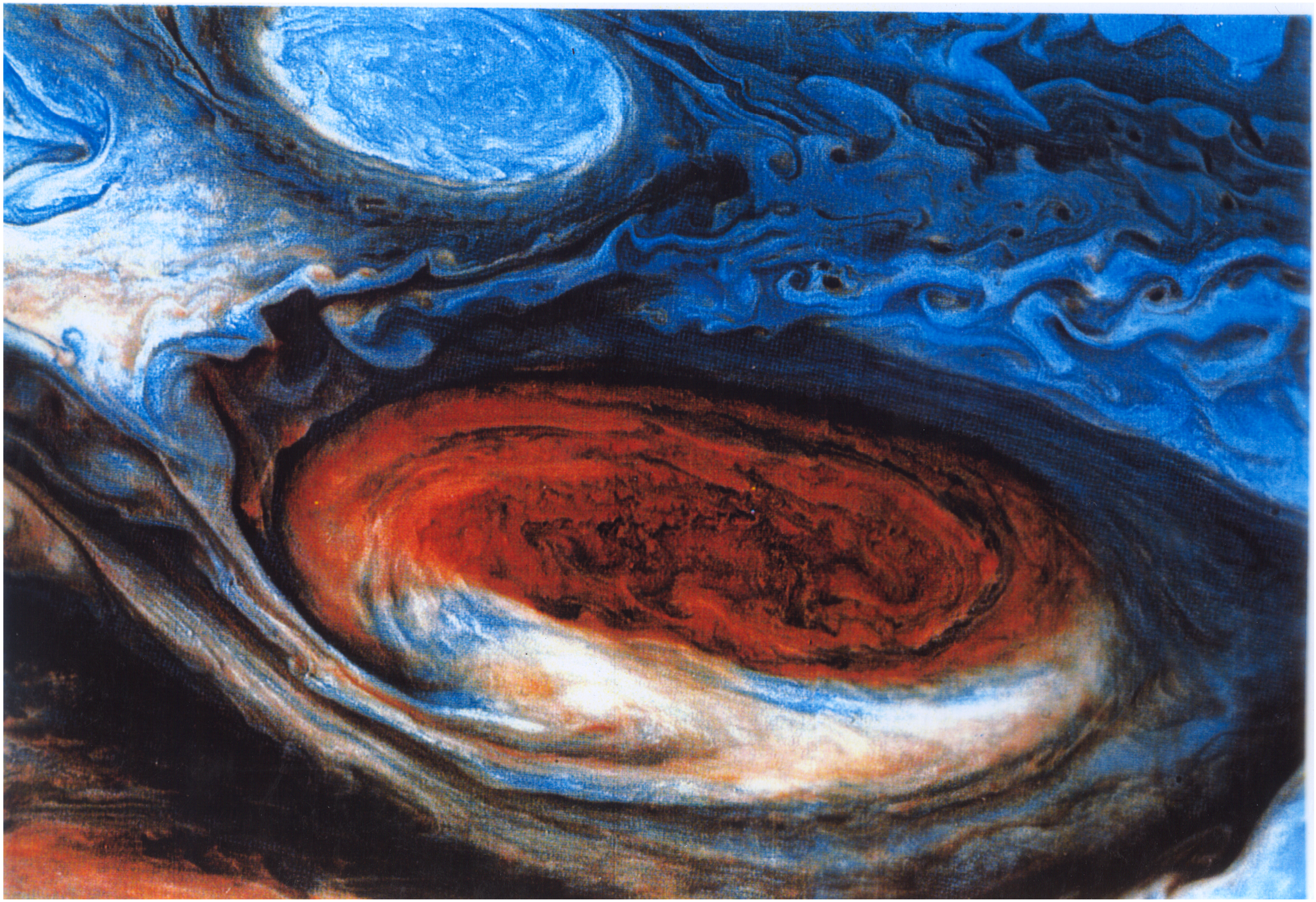
cake of soap-200x

Type I Complexity

Structures repeated with variations in size shape placement.

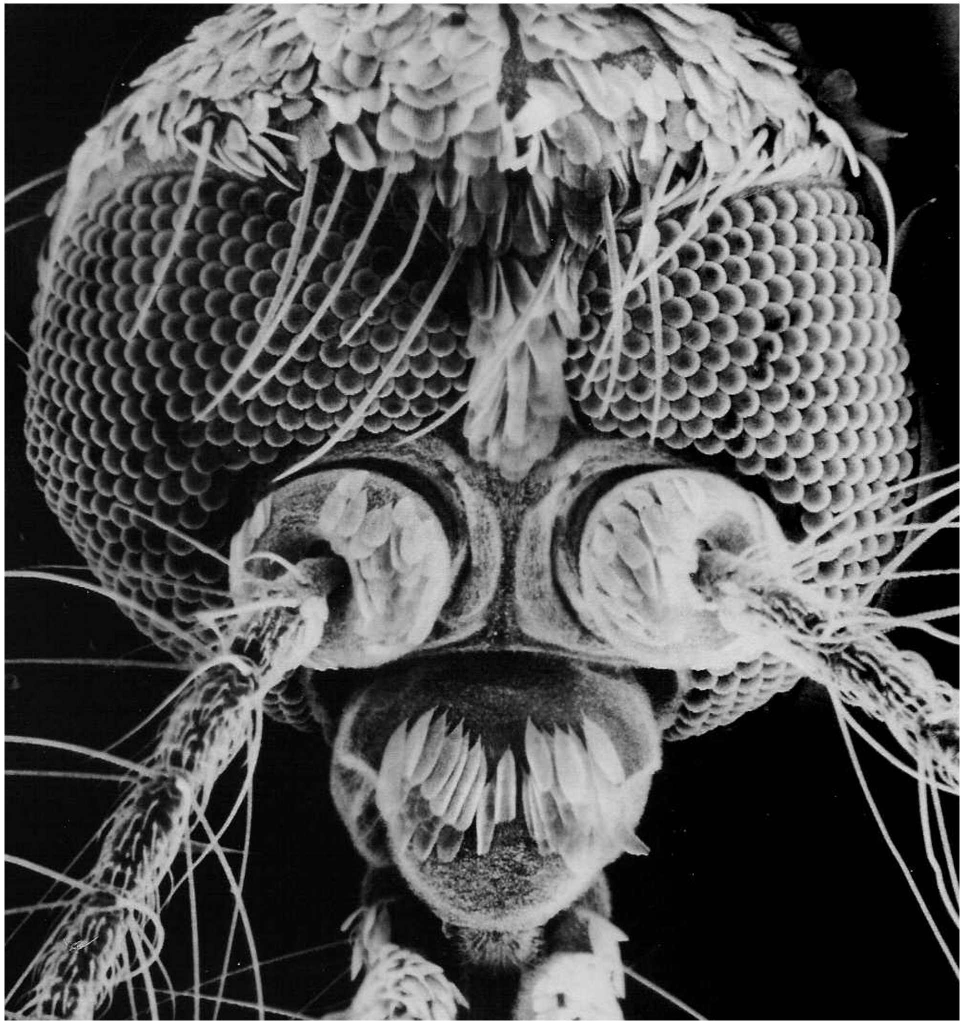
estuary

Red Spot Jupiter:
different thing happen in different places



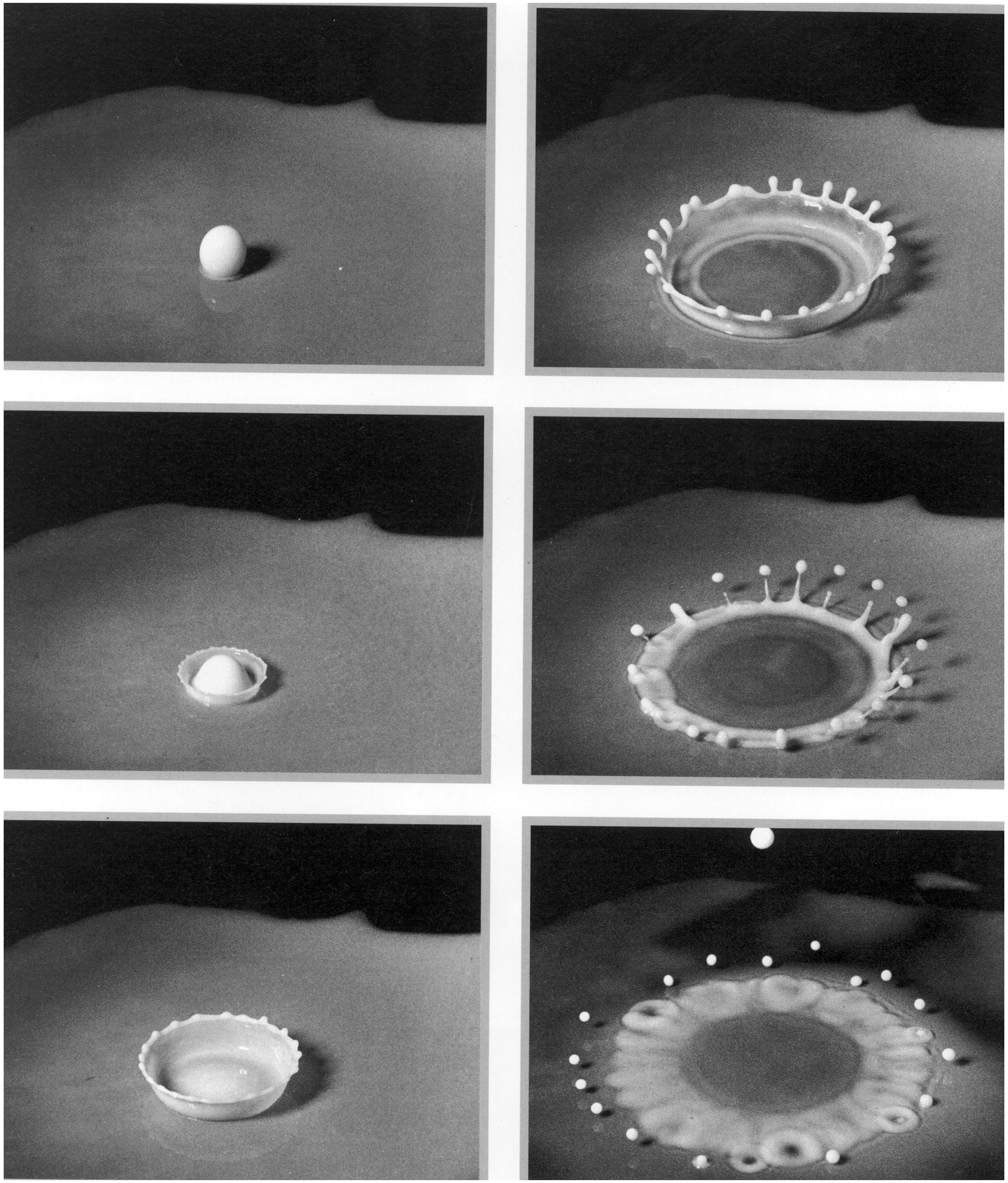
Type II Complexity

Many different structures working together, all for an apparent purpose (bite us).



mosquito- 200x

A complex result produced simply: Splash Dynamics



Harold Edgerton photo

Words

Type I Complexity means that we have structure with variations. (The soap.)

Type II Complexity means structures are piled upon structures to achieve an apparent purpose. (The Mosquito.)

Chaos means that there are many different variations and that it is hard to predict which one will come out in a given place and time. (The splash.)

A Complex world is interesting

In a Chaotic world we do not know what is coming next

Our world is both Complex and Chaotic

Behe's Unlikely World

Michael Behe argues that biological objects, cells in particular, are too complex to have arisen from any natural process. They are composed of many working parts and each part is necessary for the organism to function. How could so many parts evolve independently?

Since he cannot imagine any natural process which might have produced them, Behe argues that such a complex outcome requires a creator or Creator.

Behe's argument is mostly theoretical It depends upon the strength of his imagination.

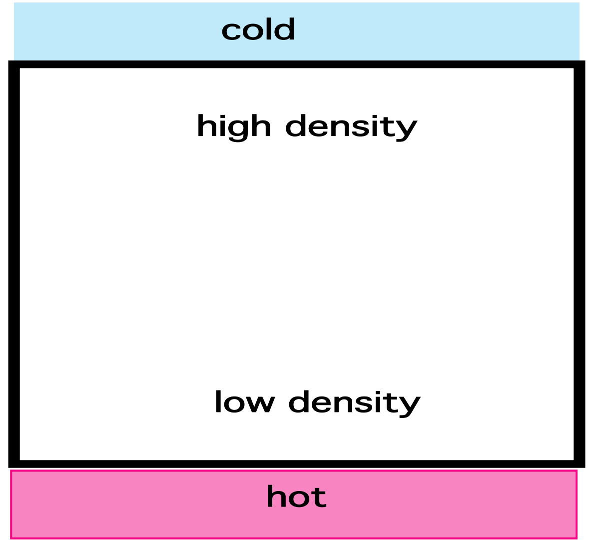
Let's be more real.

Let's look and see how complexity actually arises in our world.

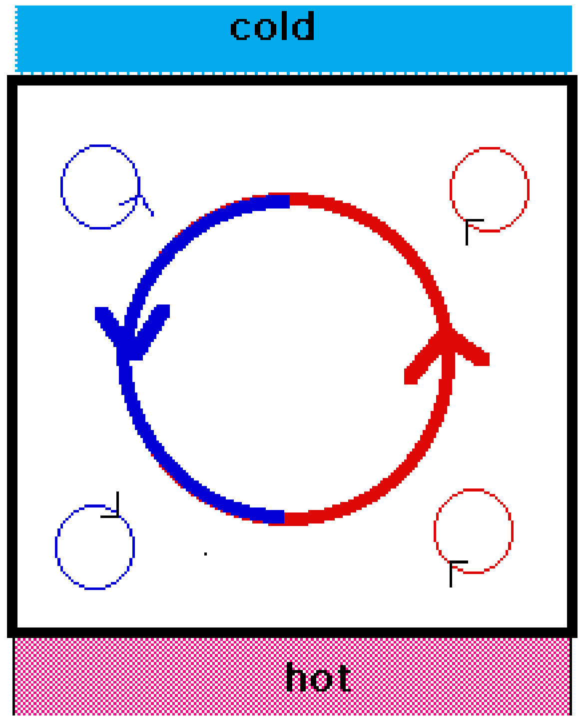
Look at a particular fluid flow.

Fluids Heated From Below

Start from a box filled with fluid. A little heating of system from below causes no motion of fluid.



A larger temperature difference between top and bottom causes a motion of the fluid, carrying additional heat from bottom to top.



Beginning of Chaos

Then as the temperature difference is increased still further the motion of the swirls becomes non-repeating and chaotic with different portions of the cell wiggling independently of one another.

Turbulence

Then for slightly higher heating rates a different pattern emerges:

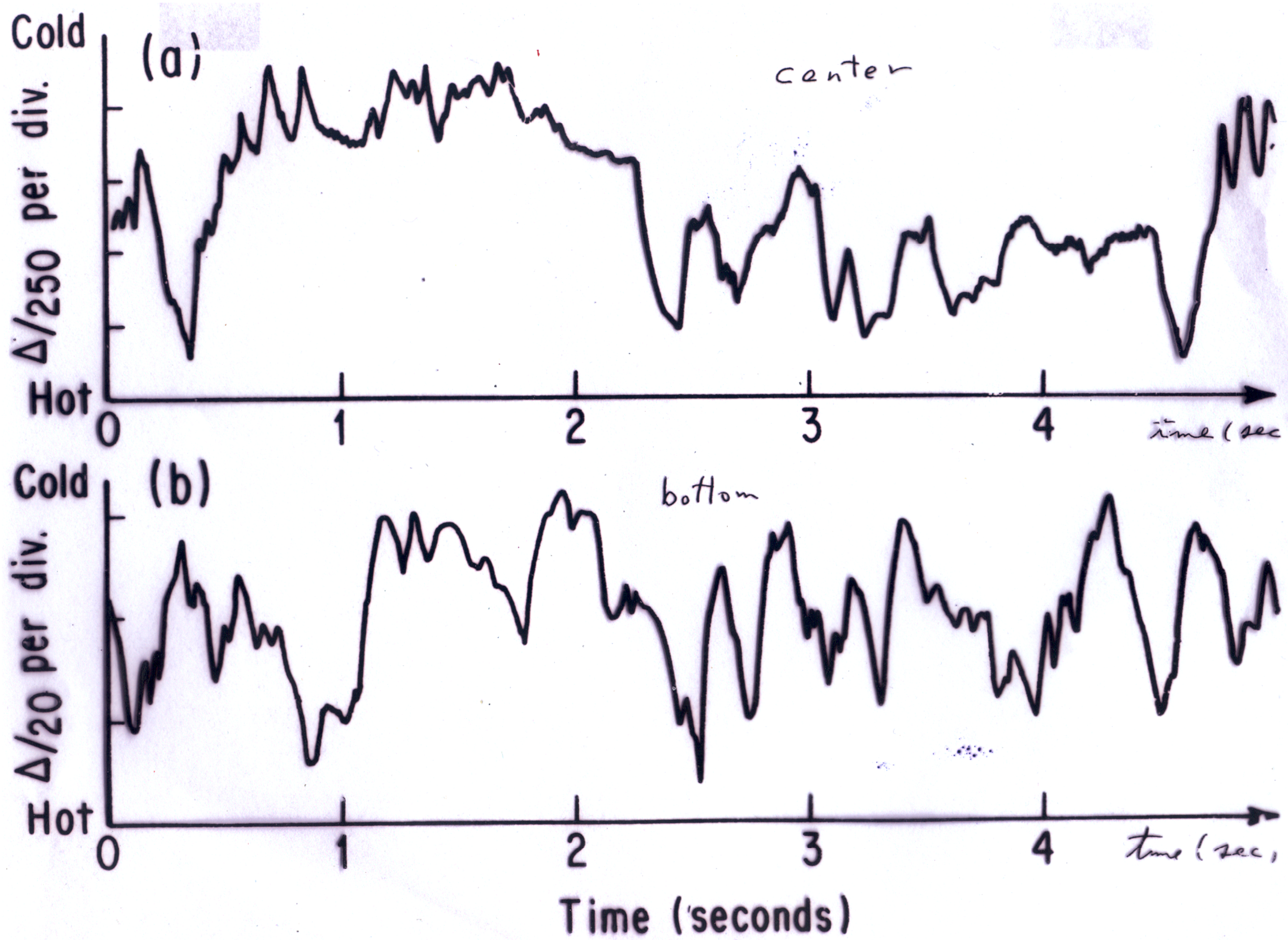
There is an overall motion, here counterclockwise, which becomes composed of independently moving structures, called plumes. They look a little like mushrooms.

picture from Penger Tong's laboratory
fluid: glycol.

note thermometer in cell

Plume motion past thermometers produces chaotic readings

from laboratory of Albert Libchaber



Description via Equations

F=ma $$[\partial_t + u(r,t)\cdot\nabla]u(r,t) = -\nabla p(r,t) + \nu\nabla^2 u(r,t) + g\alpha T(r,t)$$

fluid is incompressible $$\nabla \cdot u(r,t) = 0$$

temperature flows with fluid and diffuses $$[\partial_t + u(r,t)\cdot\nabla]T(r,t) = \kappa\nabla^2 T(r,t)$$

From studying many simple situations we learn
these equation describe and predict all fluid flows

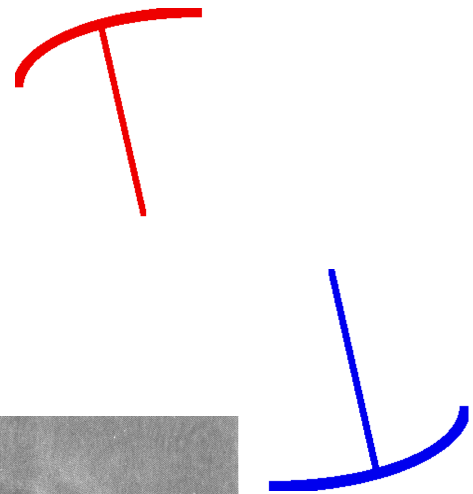
But in interesting, complex situations
mostly you cannot learn much from directly examining the equations

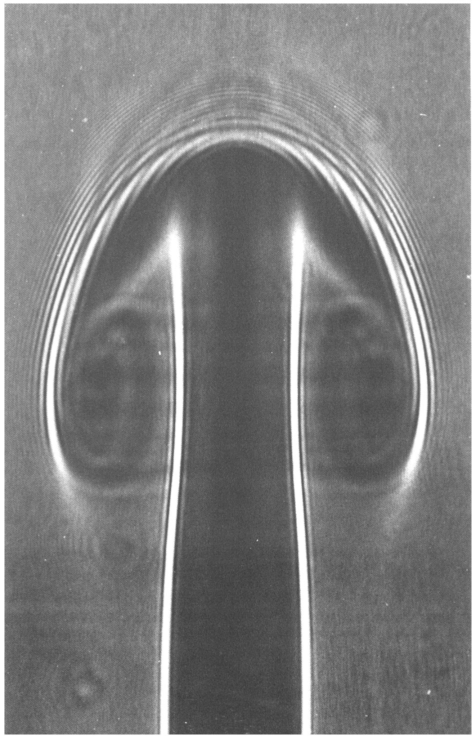
So look at structures = Plumes

Hot fluid rises through the stalk and reaches the head.

The head pushes upward but the fluid above pushes back.

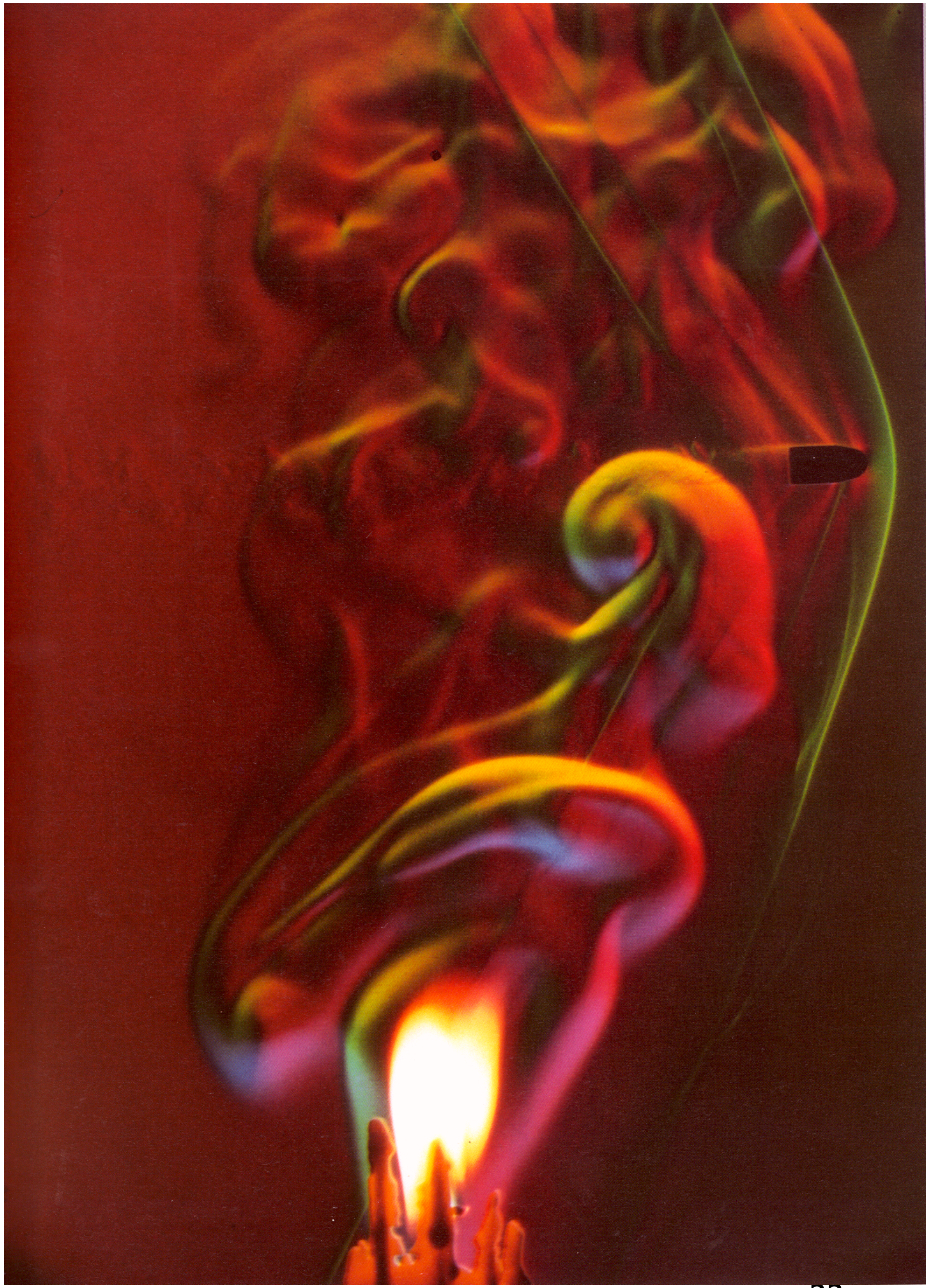
So the head grows outward, until the outward pushing hot fluid is pushed back and under by the colder fluid.



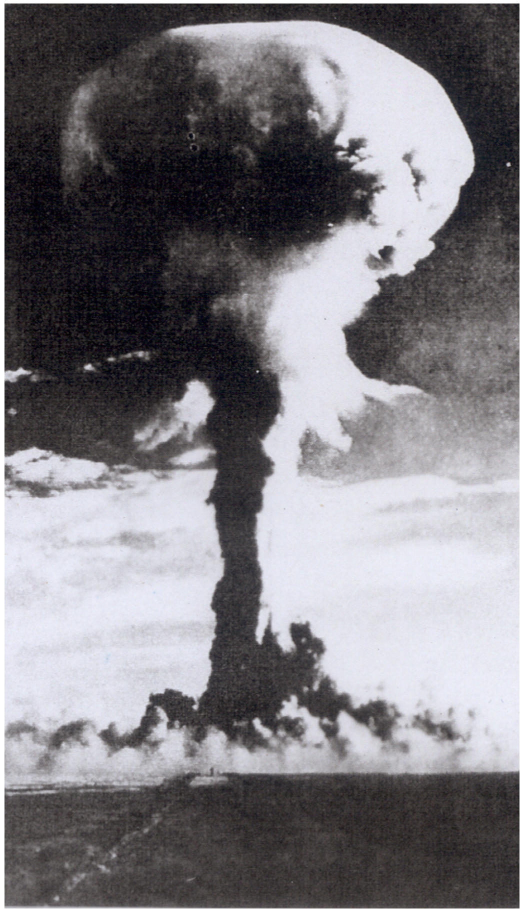


What we see in fluids inspires us to think about plumes

Plumes are everywhere fluids are heated



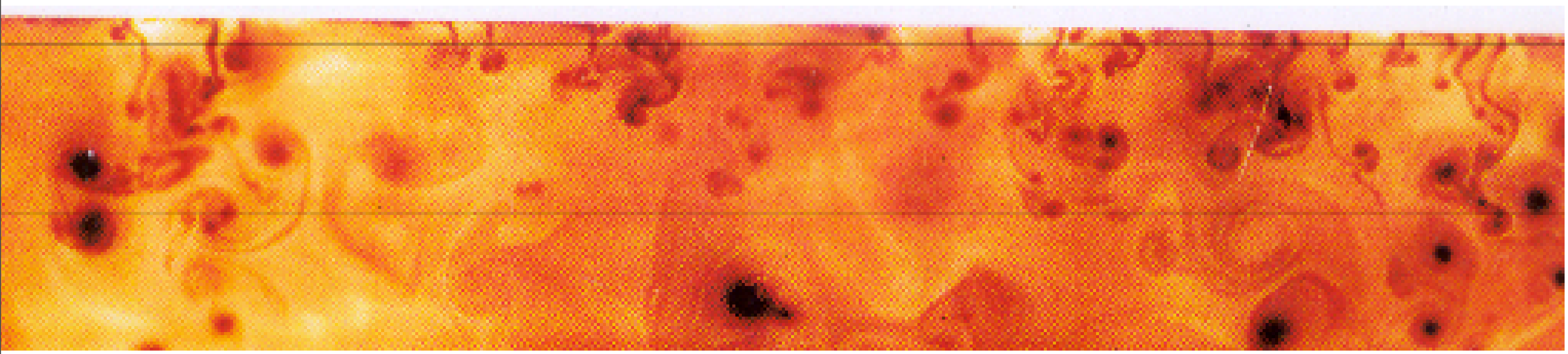
Edgerton picture of fluid heated by candle



Plume from a Nuclear Explosion

Plumes at Solar Surface

Up



Cold plumes fall
downward from surface

Colors Describe Temperature

Simulation by Malagoli, Dubey, Cattaneo

Return to fluid heated from below:

Plume Moves across bottom of Cell

time

Credit: Gluckman, Williame, & Gollub 1993

The Cell Becomes a Machine: Photo

a complex machine emerges

The plume is only a part of a more complex ‘Machine’: How does the machine work? first look at the cell

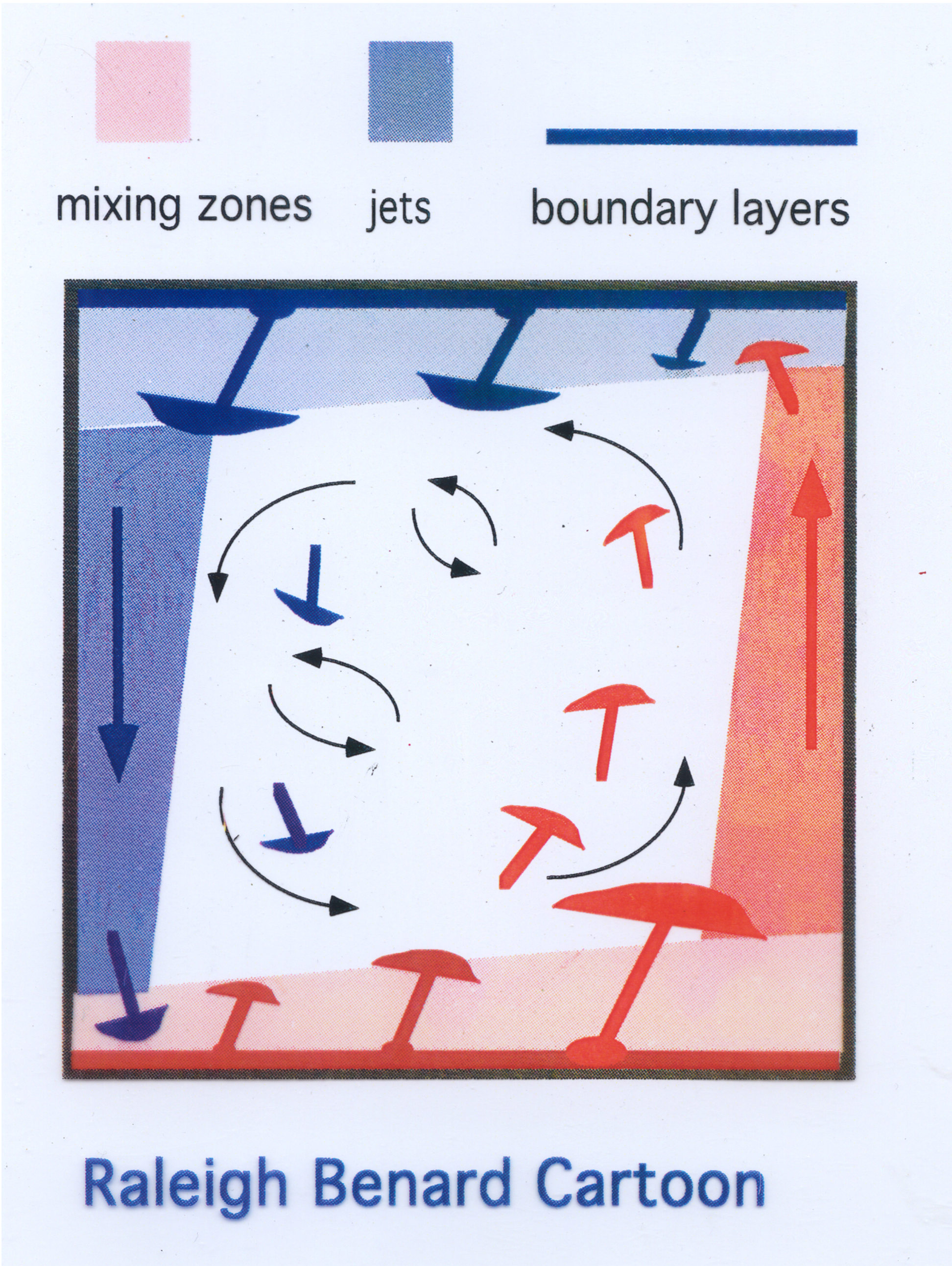
Qiu, X.-L. & Xia, K.-Q. 1998 Viscous boundary layers at the sidewall of a convection cell. Phys. Rev. E 58, 486–491.

The Cell Becomes a Machine: The Geometry

The plumes play different roles in different regions of the cell.

Note waves at the bottom

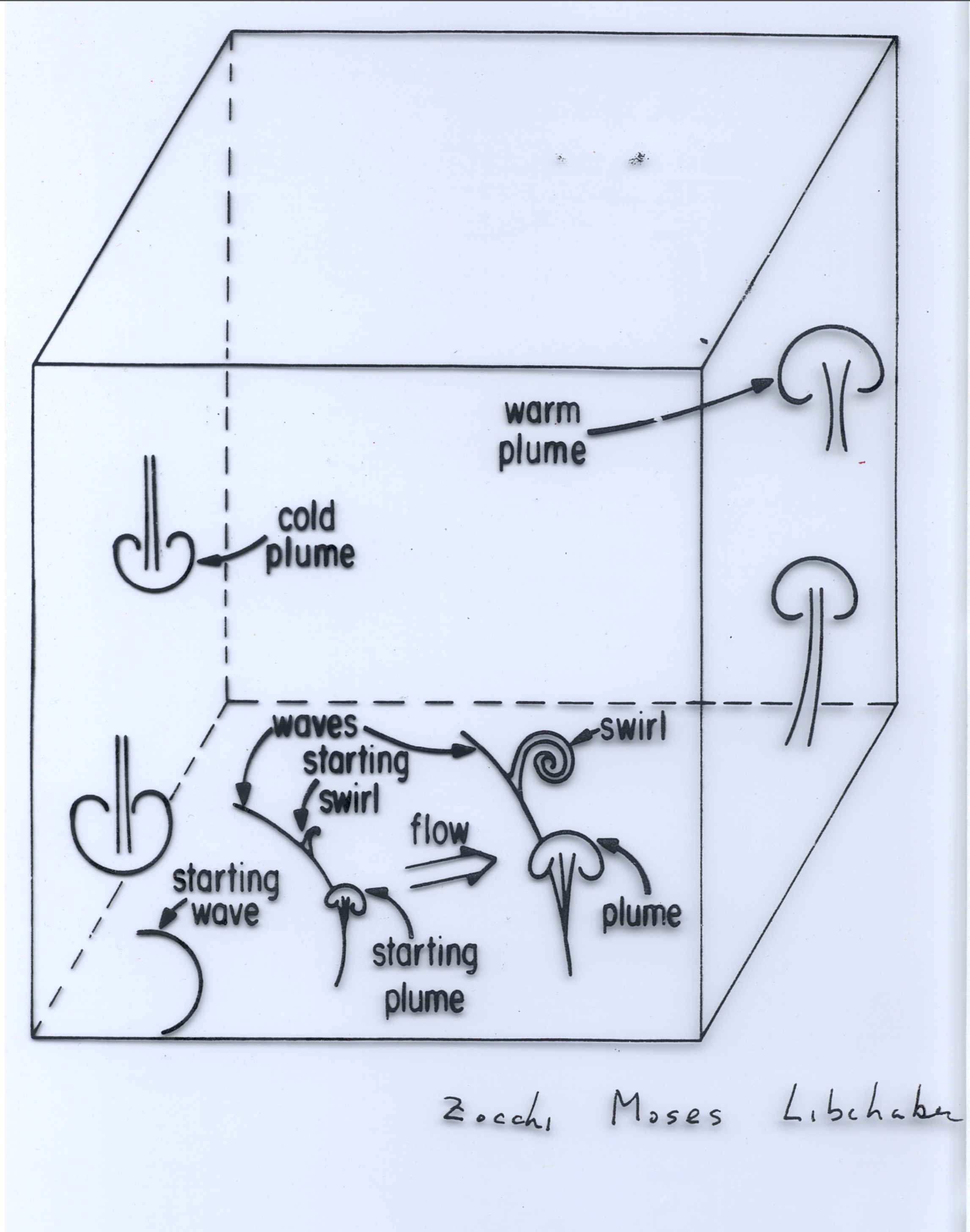
Overall flow

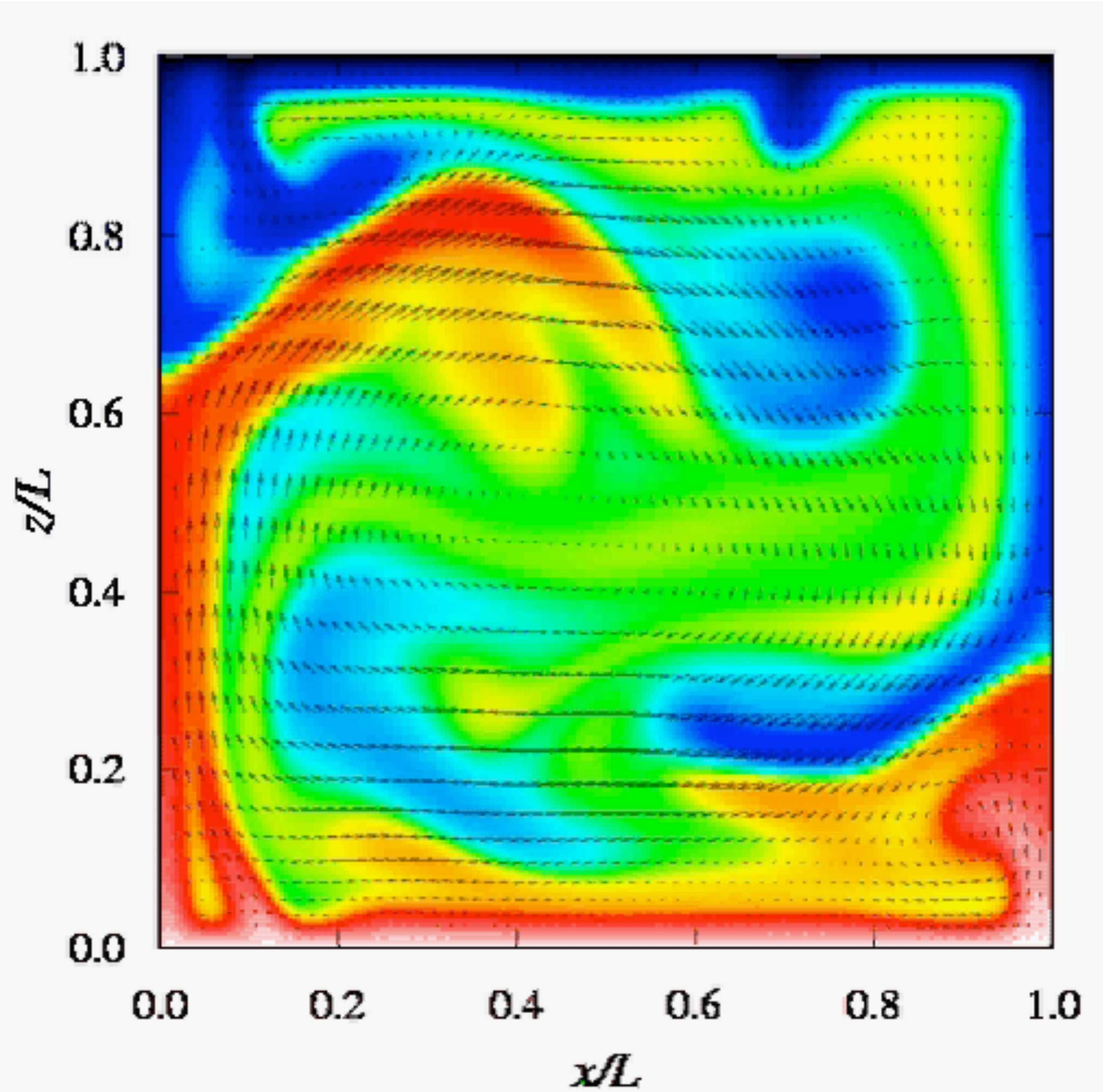


The Cell Becomes a Machine: The Dynamics

The wind in the cell starts a wave moving across the bottom of the cell...

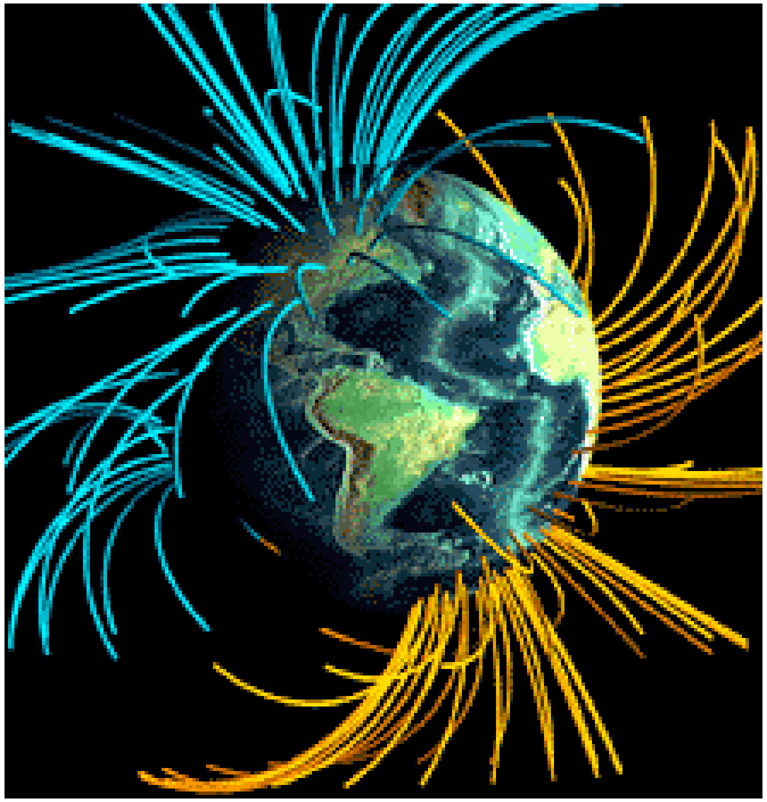
The result: Flowing fluids can organize themselves to produce the most amazing complexity with many different working parts each serving a different function.





Stevens, Richard J. A. M., Verzicco, R. & Lohse, D. 2010 Radial boundary layer structure and Nusselt number in Rayleigh-Bénard convection. J. Fluid Mech. 643, 493–507

Occasionally earth's magnetic field also reverses



last time was about 1,000,000 years ago. Maybe mechanisms are similar to reversal in RB cell.But here, Coriolis force count.

Wikipedia:In 1963 Frederick Vine and Drummond Matthews provided a simple explanation [of magnetic reversals] [….].[2] Canadian L. W. Morley independently proposed a similar explanation in January 1963, but his work was rejected by the scientific journals Nature and Journal of Geophysical Research, and not published until 1967 in the literary magazine Saturday Review.[1] The Morley–Vine–Matthews hypothesis was the first key scientific test of the seafloor spreading theory of continental drift.

credits: Detlef Lohse
G.A. Glatzmaier and P.H. Roberts
Ke-Qing Xia

Behe's world and ours

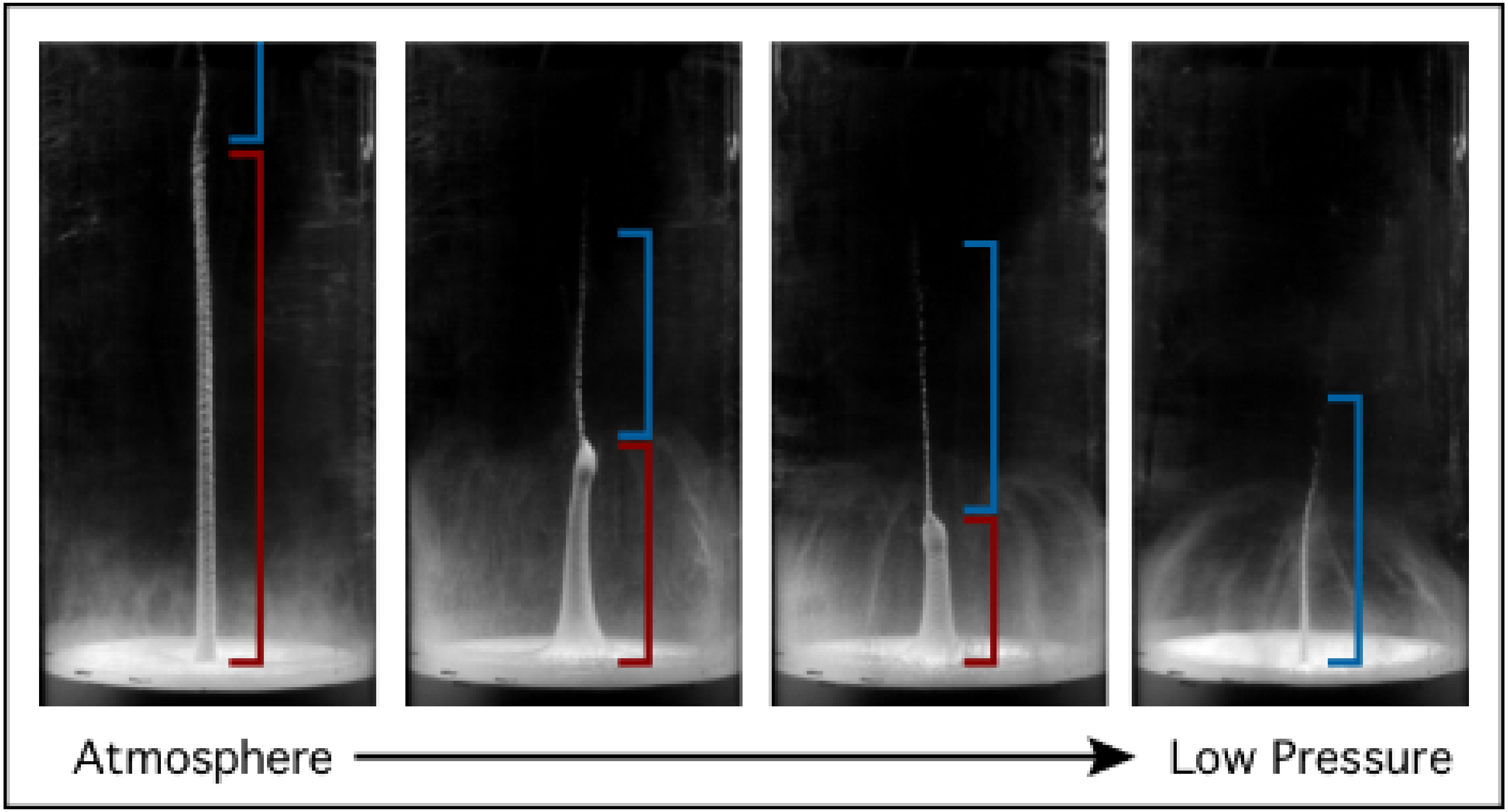
Behe cannot imagine how a thing as complex as a living cell might have been produced.

In physics we often see things that are far beyond our initial imagination and expectation.

Behe thinks he can predict when complexity will arise...but the world is full of surprises

sand jets: A metal ball is dropped into uncompacted sand

two jets emerge



credit: H. Jaeger group

The world is full of surprises

Ethanol is dropped into a dry saucer.

Work of Nagel, Zhang, Lei Xu.

547 torr

242 torr

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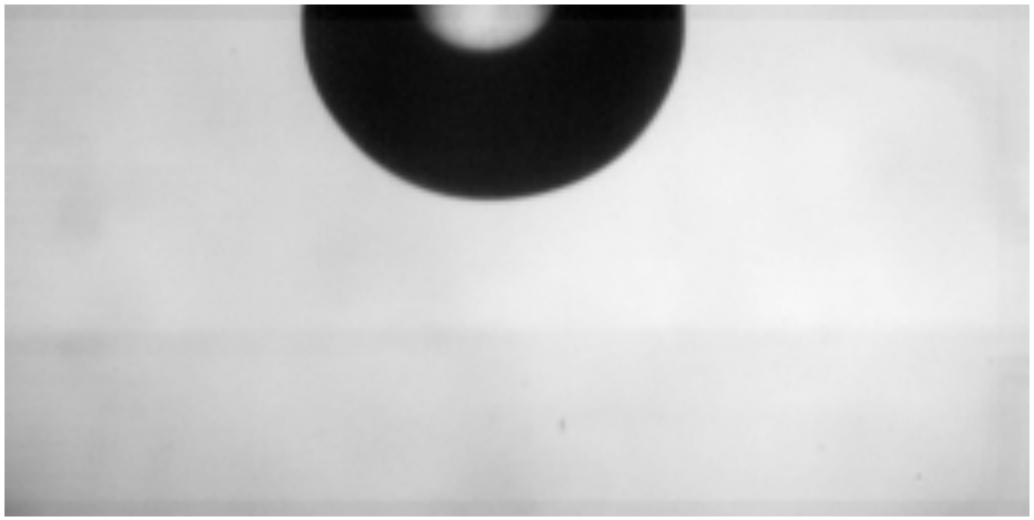

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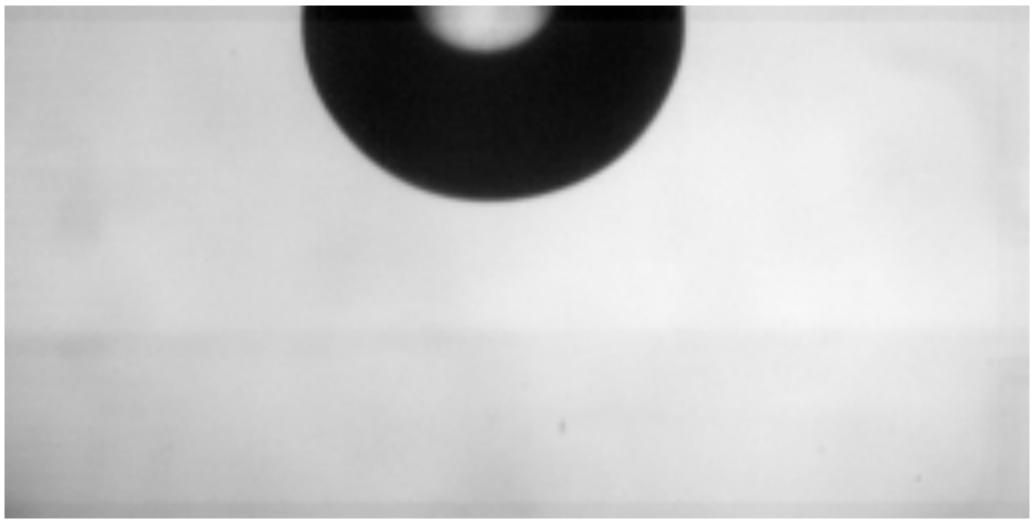

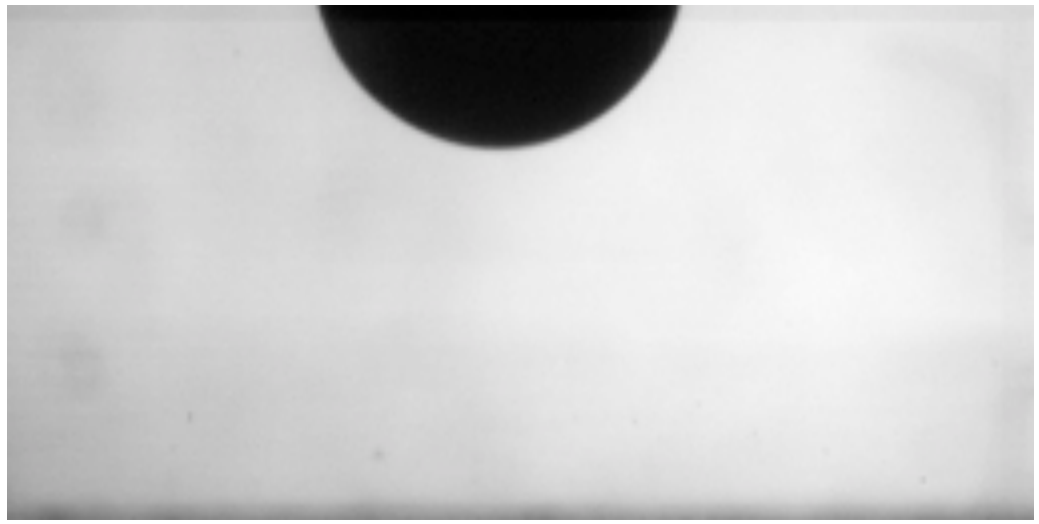

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Fluids in Motion: A square dance

theory: four basic ideas define fluid mechanics.

First:. A fluid contains many particles in motion

Second: ‘conservation laws’: some things (particles and momentum) are never lost only moved around

Third: momentum moves with the particles

Fourth: Technical requirements (translational invariance, rotational invariance, locality)

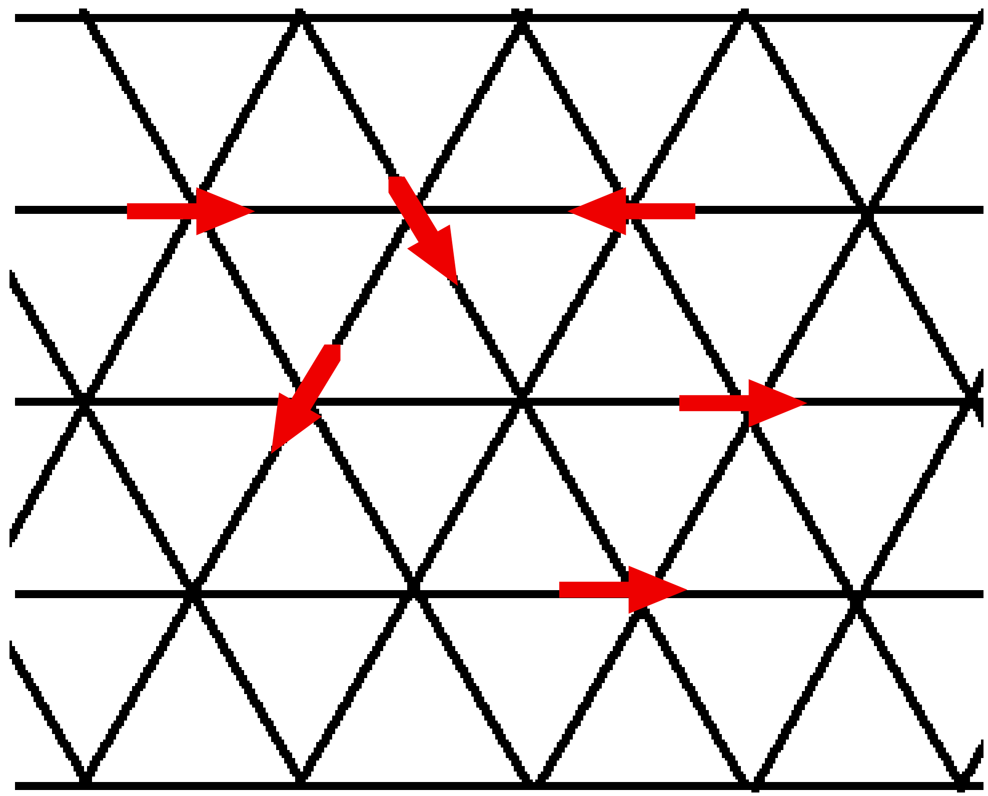
The big idea: Do the above right (plus a little more or maybe a little less.) and you will construct a model fluid with behavior just like a real one.

The Model System: A dance on a lattice

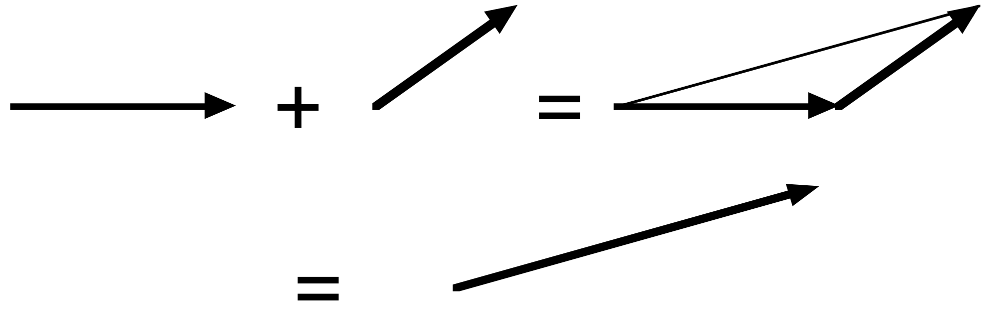
The Dance floor: A regular triangular lattice.

The Dancers=particles sit on the intersections of the lattice.

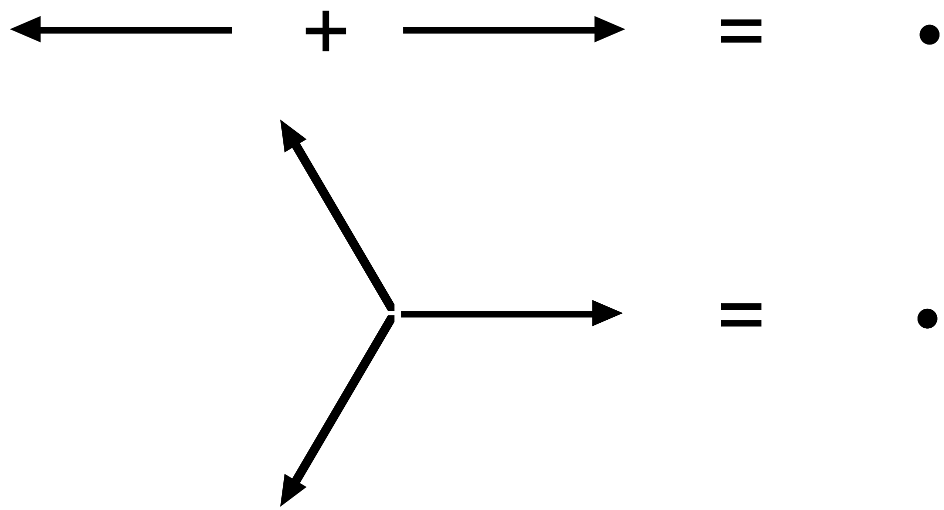
dancers have a position and a direction. There are six possible directions. (The direction is a momentum.).



The Rules for Adding Momentum



Configurations which
add up to Zero



The Dance

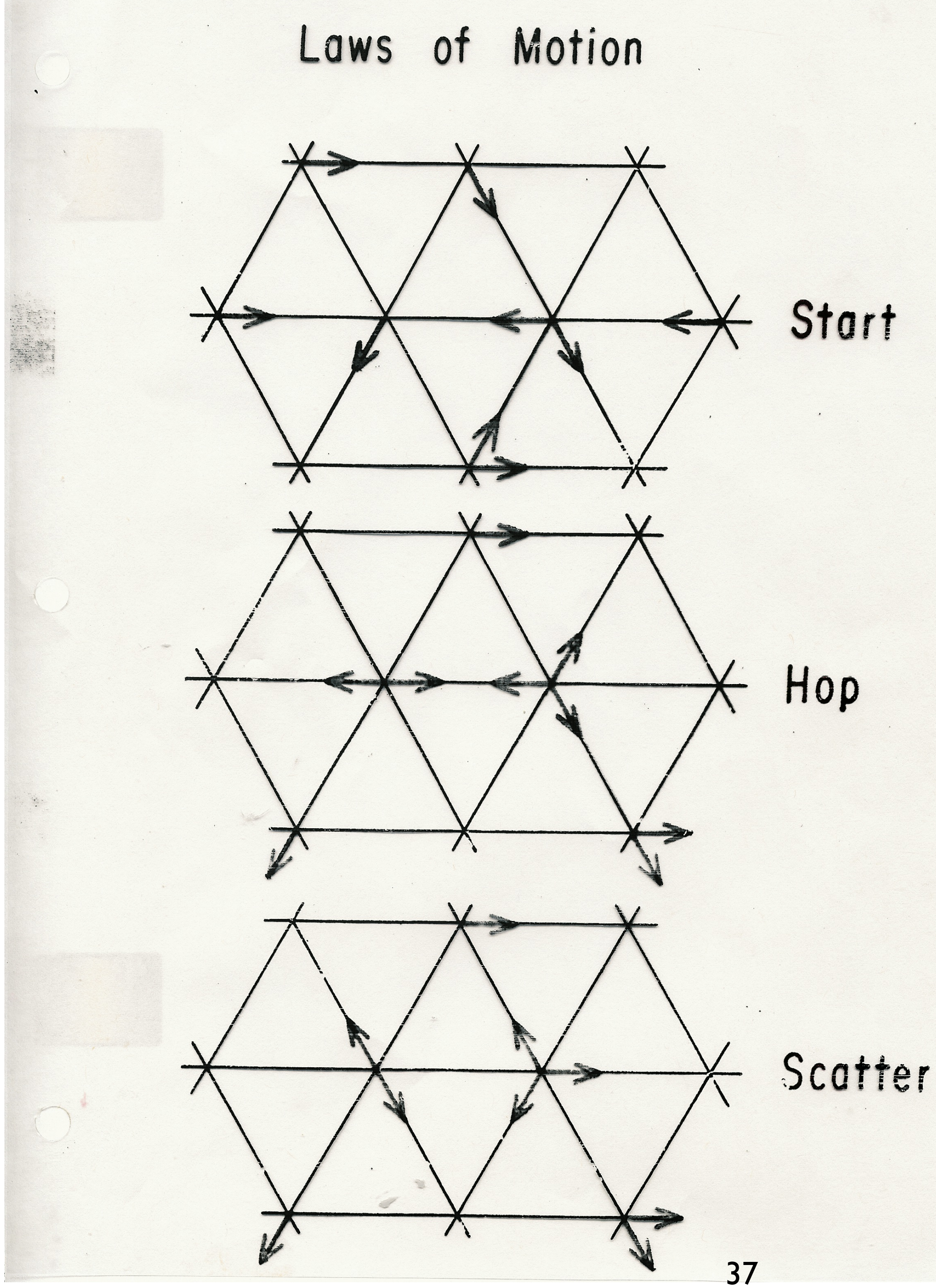
two steps:

1. the caller cries promenade each dancer moves one step in the direction of his/her arrow

2. when the caller cries swing your partner the dancers on each site with zero total momentum all rotate through 60 degrees.

(conserve the number of dancers and their total momentum.)

do 1, 2, 1, 2 ......



Frisch, Hasslacher & Pomeau, 1982

Result--Flow past cylinder

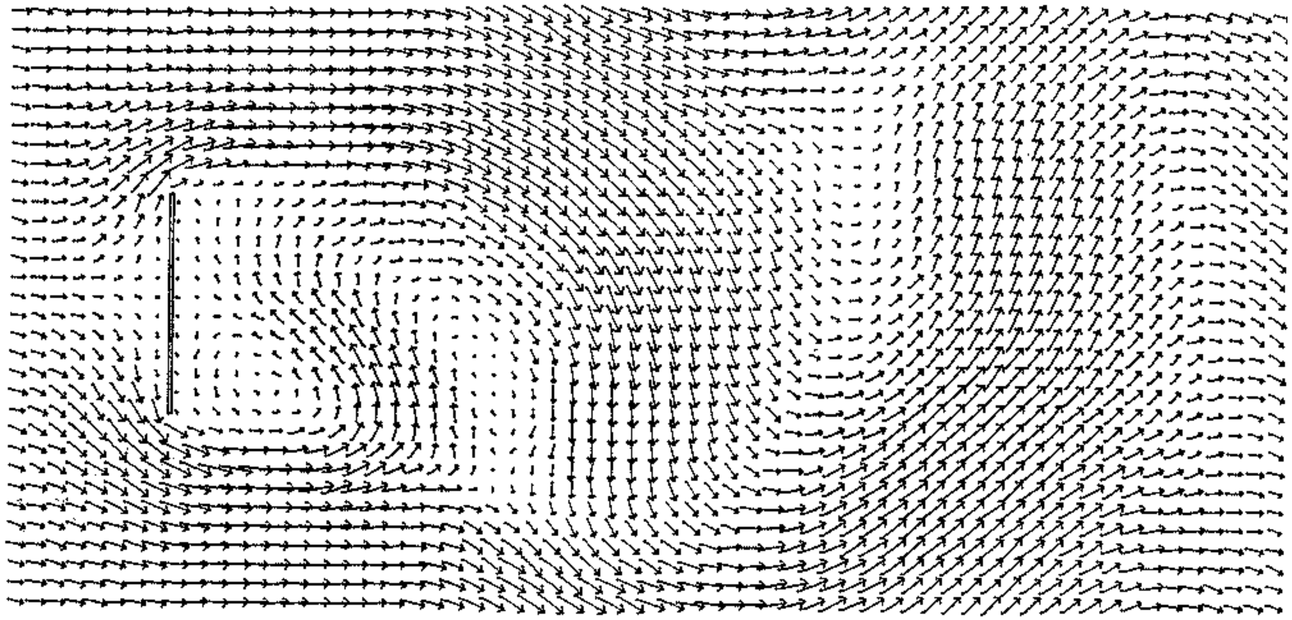
top is a computer run of the square dance with about one million dancers on a 2000 by 1000 grid. Each arrow is the average momentum of 100 dancers in the region.

A screen on the left reflects each dancer who hits it, and produces a effect akin the the cylinder in the flow experiment shown below.

bottom is a fluid flow

Notice the similarity between the two patterns of motion.

simulation by d'Humieres, Shimonura, and Lallemand



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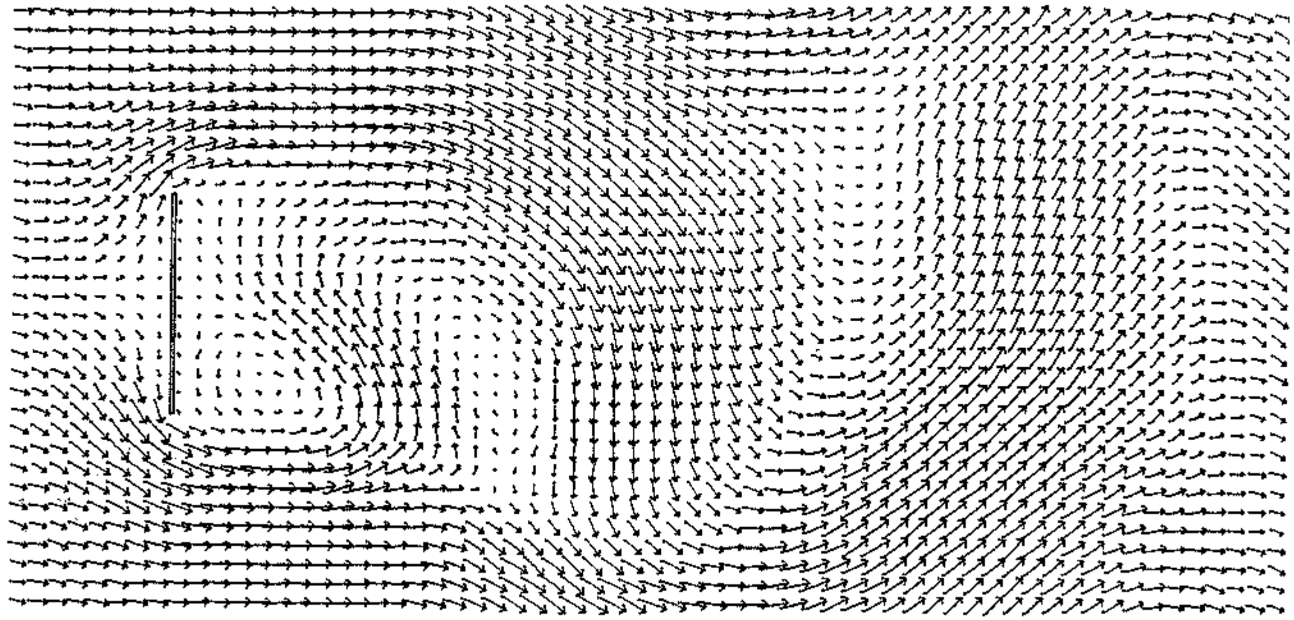

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Patterns of Fluid Flow emerge from the square dance

Very simple ingredients can produce very beautiful, rich, and patterned outputs. Thus, our square dancers through their simple "promenades" and "swing your partners" make a complex flow pattern. This flow pattern is described by the Navier Stokes equations. So are fluids.

Consequently, the square dance contains the entire beautiful world of complex patterns produced by fluid motion.

For this complexity no intelligent creator is necessary. Simple events, linked together, and repeated sufficiently often can produce complex outcomes.

Conclusion I

Our examples show that simple rules applied many times can make structures (like the plume) and machines (like the heat engine) .

Thus complexity can arise from simplicity. Complex patterns arise naturally and ubiquitously. But they are not in themselves sufficient to start to explain "life". What if ... these patterns themselves rearranged themselves into superstructures, like the "machine" we saw in the heated box, and these were chaotic and these superpatterns arranged themselves into chaotic structures..... Such piling of complexity upon complexity could work to produce the richness of biological systems.

What if biological change partly came about by having cells and organisms exchange information as DNA, through acquisition, parasitism, symbiosis and otherwise, so that whole populations evolve, rather than individuals.

Nigel Goldenfeld, Carl Woese, Lynn Margulis

Knowledge and Ignorance

We don't have much knowledge about how complexity arises, either in the physical world or for biological forms. Dembski and Behe do us some good by pointing out that ignorance, but neither they nor the ID people generally seem to have much positive to add to the discussion.

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A better view than theirs is that of of Saint Augustine of Hippo (354-430)

"The Universe was brought into being in a less than fully formed state, but was gifted with the capacity to transform itself from unformed matter into a truly marvelous array of structure and life forms"

Howard J. van Till

About school curricula

In the last 1600 years, we have learned some specifics to help flesh out Augustine's good overview. We should not let the particular view of the universe provided by ID's followers replace science in the school curricula. Instead, we should notice that

Evolutionary biology, paleontology, and cosmology are not speculations. They are root parts of science and human knowledge. They belong in schools as part of the basics of our curriculum and of our understanding of the material world.

Other subjects, unrooted in experiment, should be avoided in school science classrooms.

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